INFORMATION PROCESSING OF DATA DESCRIBING ARBITRARY SOLIDS

SEMI-ANNUAL STATUS REPORT

June 1, 1965 - November 30, 1965

Herbert Freeman
Principal Investigator

December 1965

Sponsored by
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Prepared under
Grant NGR-33-016-038

N66 81461 (ACCESSION NUMBER)
11 (PAGES)
CR-70076 (NASA CR OR TMX OR AD NUMBER)
(THRU) None (CODE)
(CATEGORY)
FACILITY FORM 602

LABORATORY FOR ELECTROSCIENCE RESEARCH

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INFORMATION PROCESSING OF DATA DESCRIBING ARBITRARY SOLIDS

I. INTRODUCTION

This status report describes the research studies carried out in the Department of Electrical Engineering, New York University, during the period from June 1, 1965 to November 30, 1965, relating to the information processing of data describing arbitrary solids. The work is being sponsored by the National Aeronautics and Space Administration under grant NGR-33-016-038. This report covers the first six-months period of a planned two-year program.

The objective of the research is to develop techniques for the analysis and manipulation of arbitrary three-dimensional geometric configurations by means of a digital computer. One problem of particular interest is that of obtaining perspective projections of arbitrary solids illuminated from a point source of light. The techniques (computer algorithms) to be developed are to facilitate the solution of this problem as well as to be of general utility to the solution of many other problems that involve the computer manipulation of data describing three-dimensional solids.

Two investigations were undertaken during this initial period of the research program. The first was concerned with developing a basic graphical manipulation program for a digital computer. This program will serve as the core of an eventual programming system for the three-dimensional analysis algorithms to be developed. The second investigation was

directed toward obtaining a clearer understanding of the topological properties of contour maps and to determine how these properties might be applied to the solution of problems involving solids described by contour maps. Reports describing the initial efforts of both investigations have been prepared.[1,2]

II. DEVELOPMENT OF GRAPHPAK I

One of the prime objectives of the research program is to develop computer algorithms for the manipulation of data defining arbitrary solids. It was realized from the outset that to test and evaluate such algorithms, it would be necessary to have available a general graphical programming system. As an initial effort toward obtaining such a programming system, a program called GRAPHPAK I was developed. The program was written for a PDP-5 computer. This computer is equipped with a direct digital plotting device and will be used for most of the anticipated computer work. A CDC 6600 computer is also available for large-scale calculations; however, all output plotting will be performed on the PDP-5 computer.

GRAPHPAK I is a man-machine interaction program that permits an operator to insert data describing any arbitrary three-dimensional "wire-frame" figure having up to 64 vertices. The coordinates of the vertices as well as all the lines connecting vertices must be specified by the operator. The operator may then instruct the program to rotate the figure, to change its scale, to translate it, as well as to move it closer or farther away from his "eye". Whenever the operator requests an output, the computer plots out a true perspective projection of the figure as currently stored in the computer memory. The operator may make changes in the figure, selectively distort it at will, perform other manipulations, and request output plots at various stages. An isometric projection can be obtained by making the "eye-point distance" very large. The program, principles of operation, as well as illustrative examples of some of the possible manipulations have been described in a report.[1]

The work thus far has served to demonstrate the strengths and weaknesses of the initial approach taken toward the development of a 3-D programming system and has suggested directions for improvement. Much valuable experience was also gained in the effective use of the PDP-5 computer for work involving the plotting of graphical data.

In its present state GRAPHPAK I is limited to the manipulation of "wire-frame" figures and has no provision for handling solids with hidden lines. However, an algorithm has been developed to handle hidden lines for the case of arbitrary convex solids.* It is planned to incorporate this algorithm in future versions of the program.

*A convex solid is a figure such that a line connecting any two points lying in its surface will be completely contained within the figure.

III. CONTOUR-MAP SEARCH PROBLEM

A comprehensive investigation has been undertaken to explore the possibilities of using contour maps for the representation of arbitrary solids. In the initial approach taken, consideration was limited to single-valued contour maps (i.e., to the conventional kind). A specific problem was selected to serve as a vehicle for developing and testing contour-map analysis techniques that are based on the topological properties of contour lines. The problem selected for this purpose is a heuristic-type search problem in which a contour map is to be searched for a particular ground path, given the map and an arbitrary air track with associated altitude profile. A problem of this type would for example be encountered by an aircraft pilot who, upon return to base, is trying to retrace his ground track on a contour map on the basis of his altitude and relative heading data recorded during flight.

It has been found that certain simple topological properties of contour maps greatly facilitate the solution of this problem. The results to date have been very encouraging and are described in a report currently being prepared for publication.[2]

IV. THE HIDDEN-LINE PROBLEM

A key problem to be solved as part of the research conducted under this program is the so-called hidden-line problem. This is the problem of determining precisely which edges of a completely arbitrary three-dimensional figure (solid) are visible and which are invisible to an observer at a specified location. If the figure is convex, the solution of the problem is relatively simple, and an algorithm for it has already been developed. A number of other investigators have developed similar hidden-line algorithms for restricted types of convex figures.* The main effort here, however, is to be directed toward the solution of the completely general (non-convex) hidden-line problem.

Work on this problem was started toward the end of the reporting period. Thus far the effort has been concentrated on finding ways of classifying the general hidden-line problem into different categories on the basis of certain constraints imposed on the shapes of the solids that are represented. Solutions for the simpler categories will be attempted first. The more complex categories may then be solved by breaking up complex figures into sets of simpler ones. Thus far the only category considered has been the one involving figures that are bounded by two parallel planes and have only quadrilateral surface sections between these planes. Problems in this category appear amenable to solution by an extension of an algorithm previously developed for the solution of the two-dimensional hidden-line problem.

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*For example, L. Roberts, "Machine Perception of 3-D Solids", Ph.D. thesis, Electrical Engineering Department, Massachusetts Institute of Technology, Cambridge, Mass. (June 1963).

V. WORK PLANNED FOR NEXT SIX-MONTHS PERIOD

For the next six-months period work on the graphical programming system will be continued, with emphasis on expanding its versatility and providing "hidden-line" capability for convex figures.

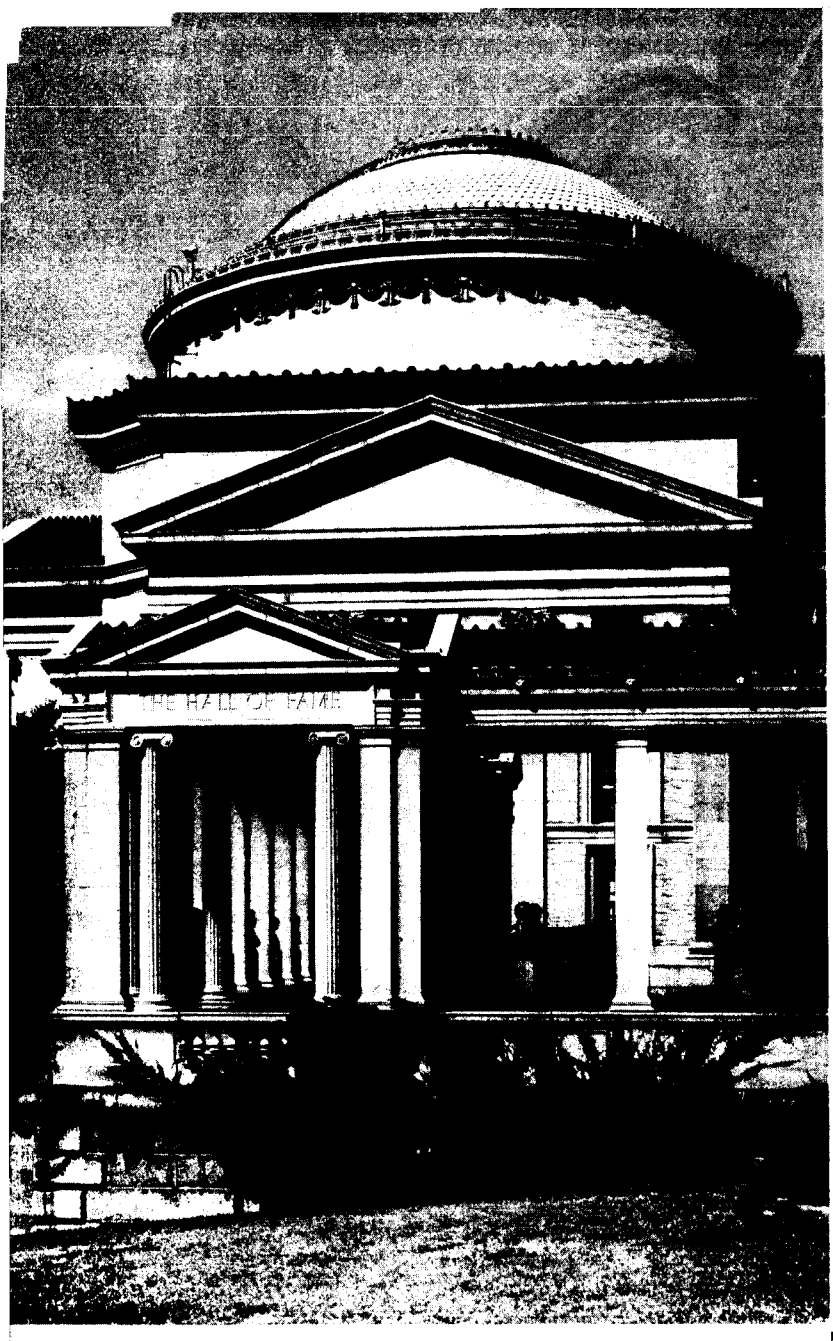
The work on the contour-map search problem will be continued. Upon the successful solution of this problem, work will be started on the "visibility" problem. The latter is the problem of determining (by means of a computer analysis of a contour map) the sections of terrain visible from a particular location.

The study of the general hidden-line problem will be concentrated on procedures for breaking up complex figures into connected sets of simpler ones, and solving the problem separately for these simpler figures. It is planned to be able to demonstrate the solution of the hidden line problem for certain limited cases on the PDP-5 computer (using the graphical programming system GRAPHPAK) toward the end of the next six-months period.

VI. REFERENCES

1. Adamowicz, M., "GRAPHPAK I - A Three-Dimensional Manipulation Program," Tech. Note 400-24, Department of Electrical Engineering, New York University, Bronx, N.Y. 10453, September 1965.

2. Morse, S., "A Topological Approach to the Problem of Searching on a Contour Map." (Draft completed - to be published as an NYU technical report in early 1966).



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